



# **Solar Spectral Irradiance Variability in Cycle 24: Model Predictions and OMI Observations**

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Climate change - known major forcing factors (no ranking...):

- **solar**
- volcanoes
- aerosols (+ clouds)
- green house gases
- ozone.

***“...most of the global warming in the 1<sup>st</sup> half of the 20<sup>th</sup> century was natural in origin, and much of this can be attributed to solar forcing.”***

Gray et al., Rev.Geophys. (2010)

... and then the green-house gases took over ...

Both the total energy input and its spectral distribution are important for climate studies.

	<b>Solar-cycle changes (~11 yrs)</b>	<b>Short-term (~monthly/weekly) changes</b>
<b>Total Solar Irradiance</b> $1360.54 \pm 0.36 \text{ W/m}^2$ (G. Kopp, 2016, priv.comm)	~0.10-0.15%	up to ~0.3%
<b>Solar Spectral Irradiance (SSI)</b> at ~ 100 nm at ~ 250 nm at > 400 nm	~100% ~1-10% <b>&lt; 0.1% (?)</b>	comparable or [much] below ? it depends...

The climate-study wish list:

regular (~weekly, at least), long-term (>10 years) spectrally resolved  
(to  $\Delta\lambda < 1-10 \text{ nm}$ ) solar observations in ~100 nm - 2  $\mu\text{m}$  range, accurate  
**(long-term!)** to

~ 1% - 0.1% (MUV-NUV)  
~ 0.01% (Vis-NIR)

... good luck with that ...

The Cycle-24 hardware (data in public domain, UV-Vis range):

**SORCE (SOLSTICE & SIM**, since Jan. 2003); multiple/day observations; 115-2400 nm, variable spectral resolution, 0.1-24.6 nm; planned long-term accuracy  $\sim$ 0.2%; achieved accuracy  $\sim$ 1-2%.

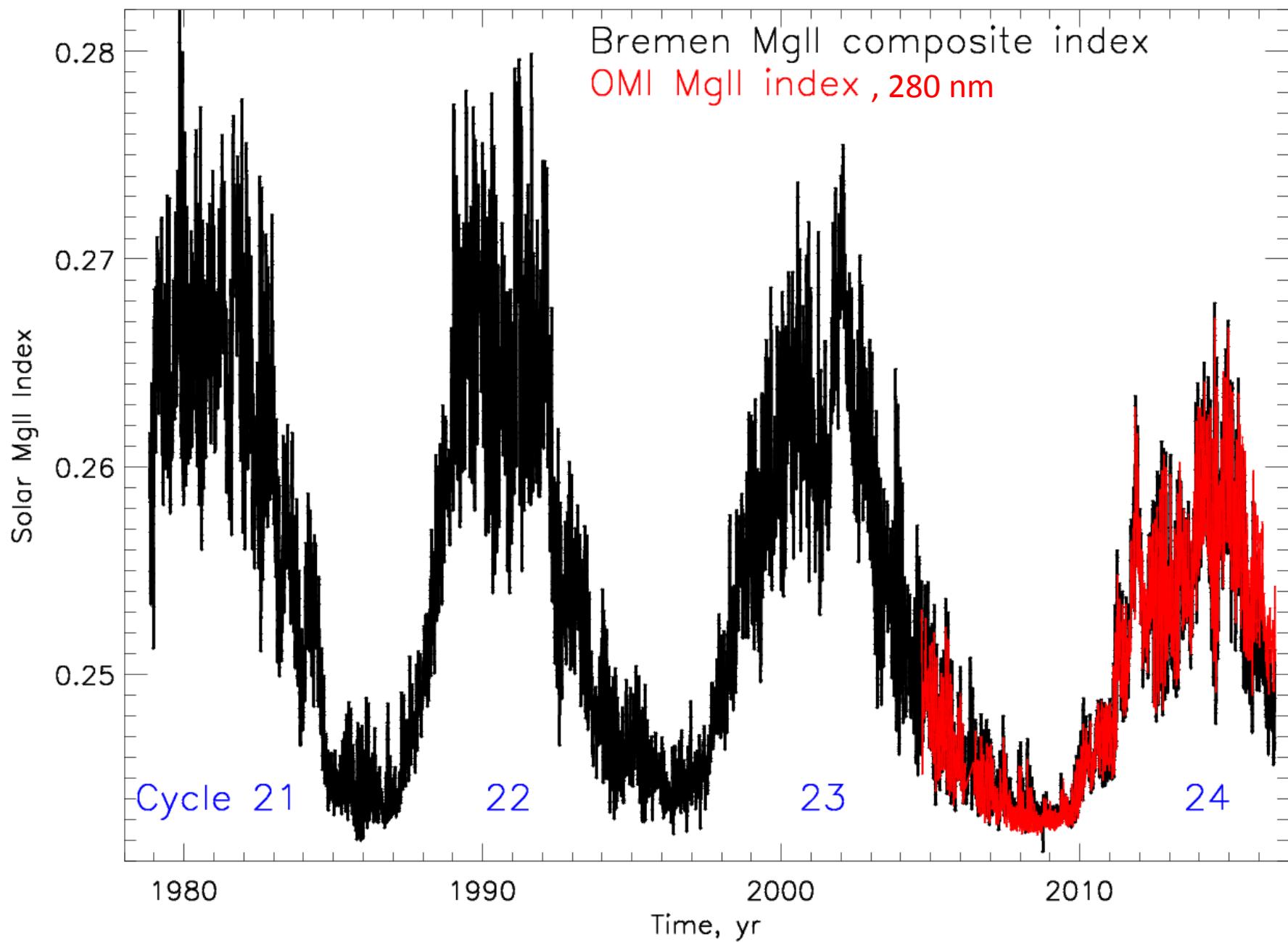
**GOME-2 A** (since Oct. 2006); daily solar observations; 240-790 nm range with 0.3-0.5nm resolution; high degradation, uncertain to  $>\sim$  1%.

**OMI** (since Jul. 2004); daily solar observations; 265-500 nm, 0.4-0.6 nm resolution; **long-term degradation (y2007-current) characterized to  $\sim$ 0.2%**.

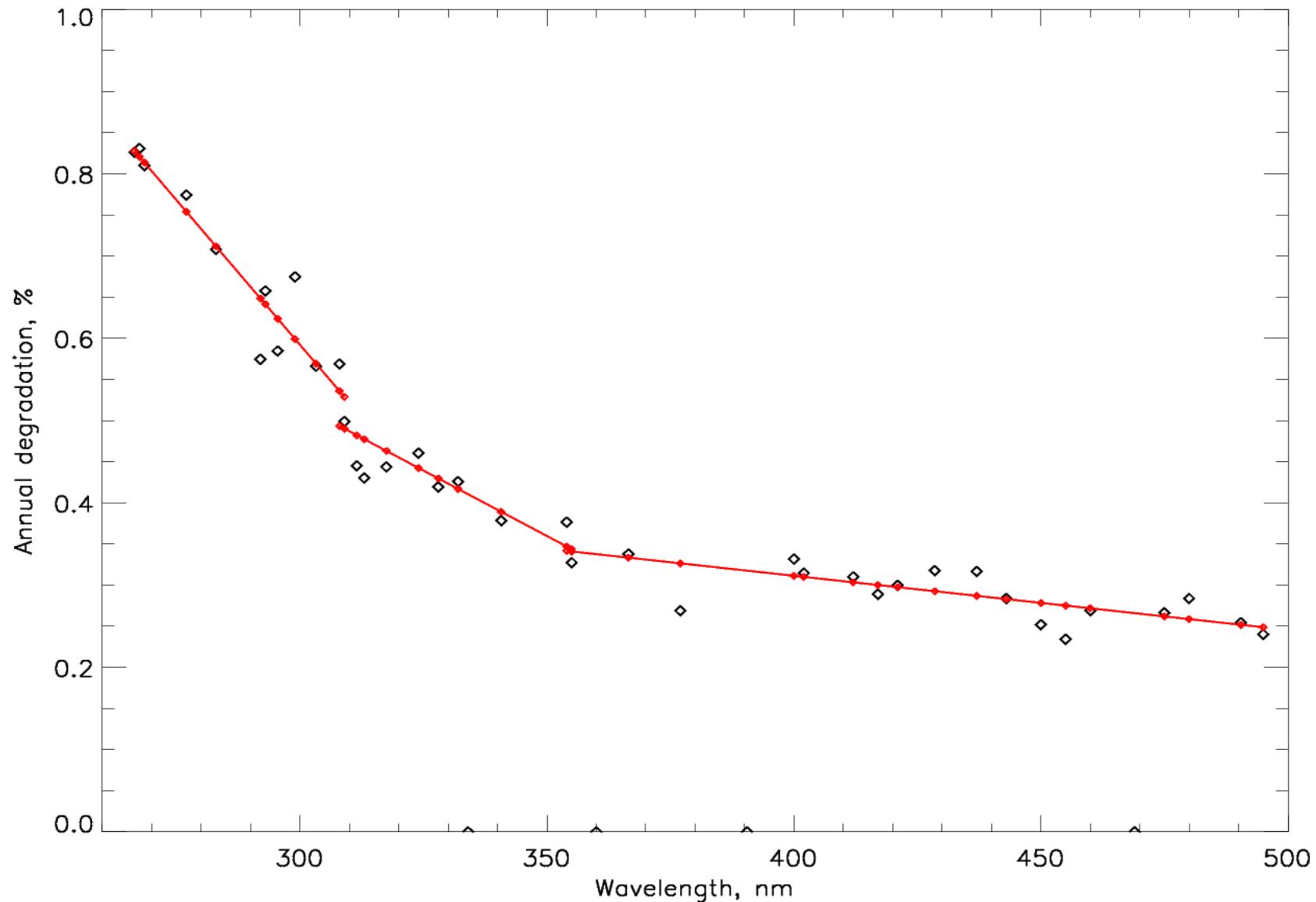
The software:

**NRLSSI2** (Coddington et al., BAMS, 2016) – the purely empirical class Naval Research Laboratory Solar Spectral Irradiance; **an operational NOAA (USA) Solar Irradiance Climate Data record**

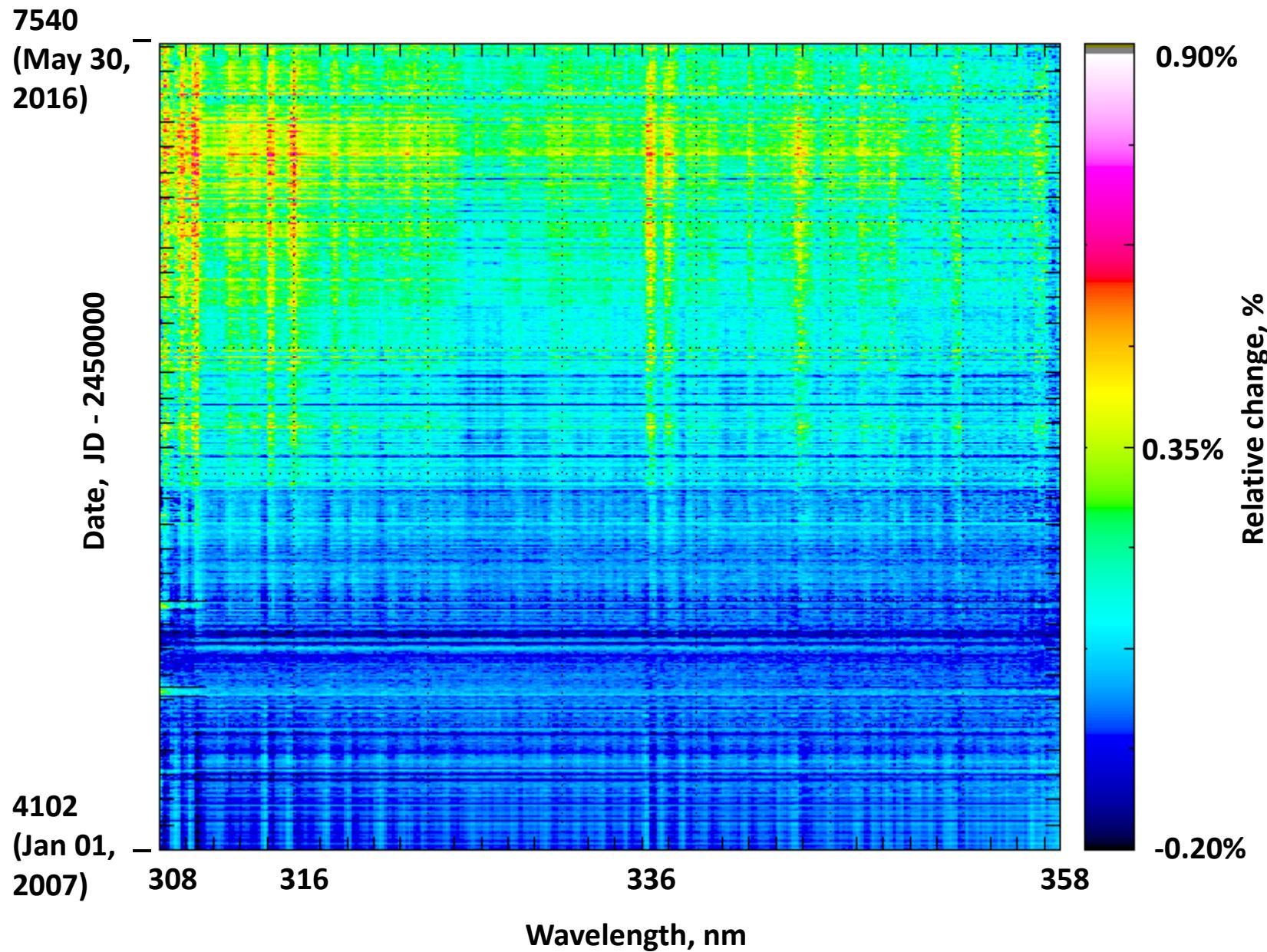
**SATIRE-S** (Yeo et al., JGRA, 120, 2015) – a representative of the semi-empirical class  
Spectral And Total Irradiance REconstruction for the Satellite era



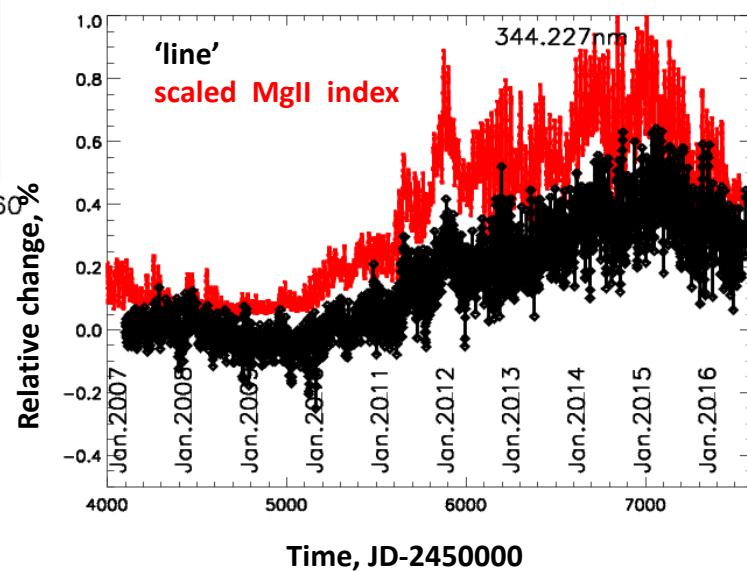
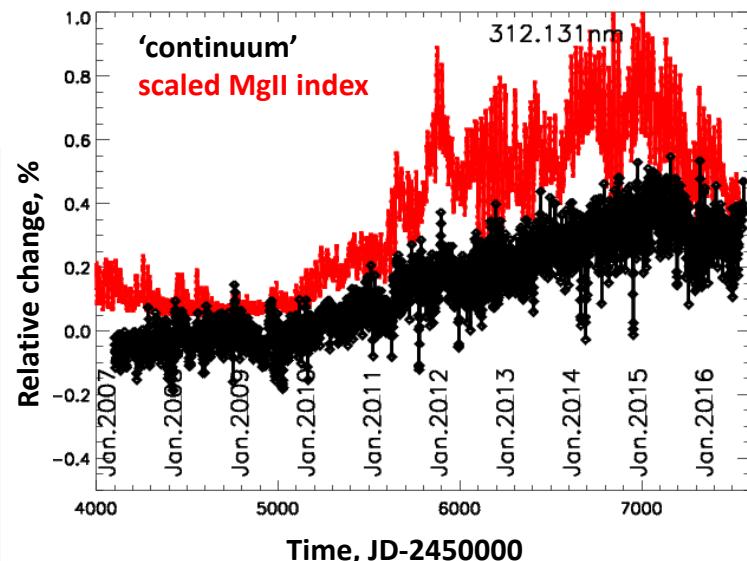
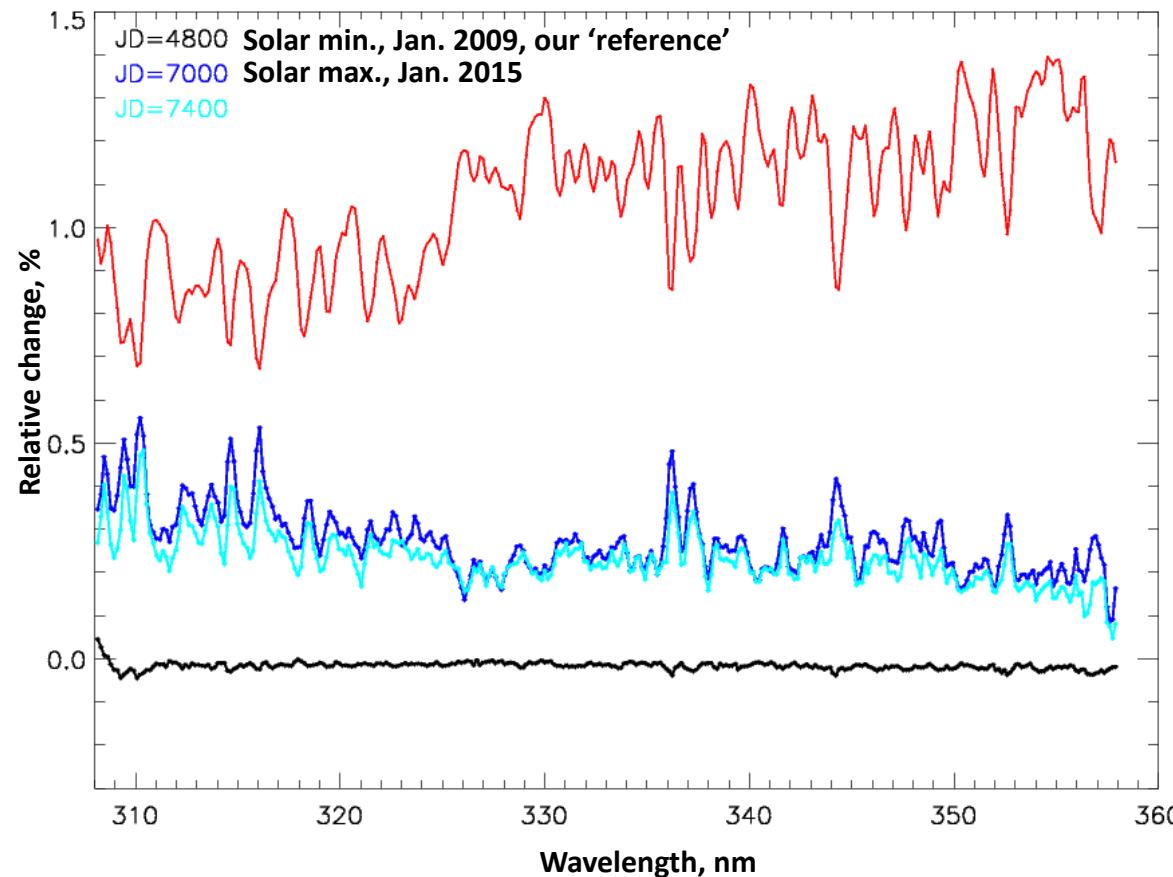
## OMI's annual degradation: irradiances



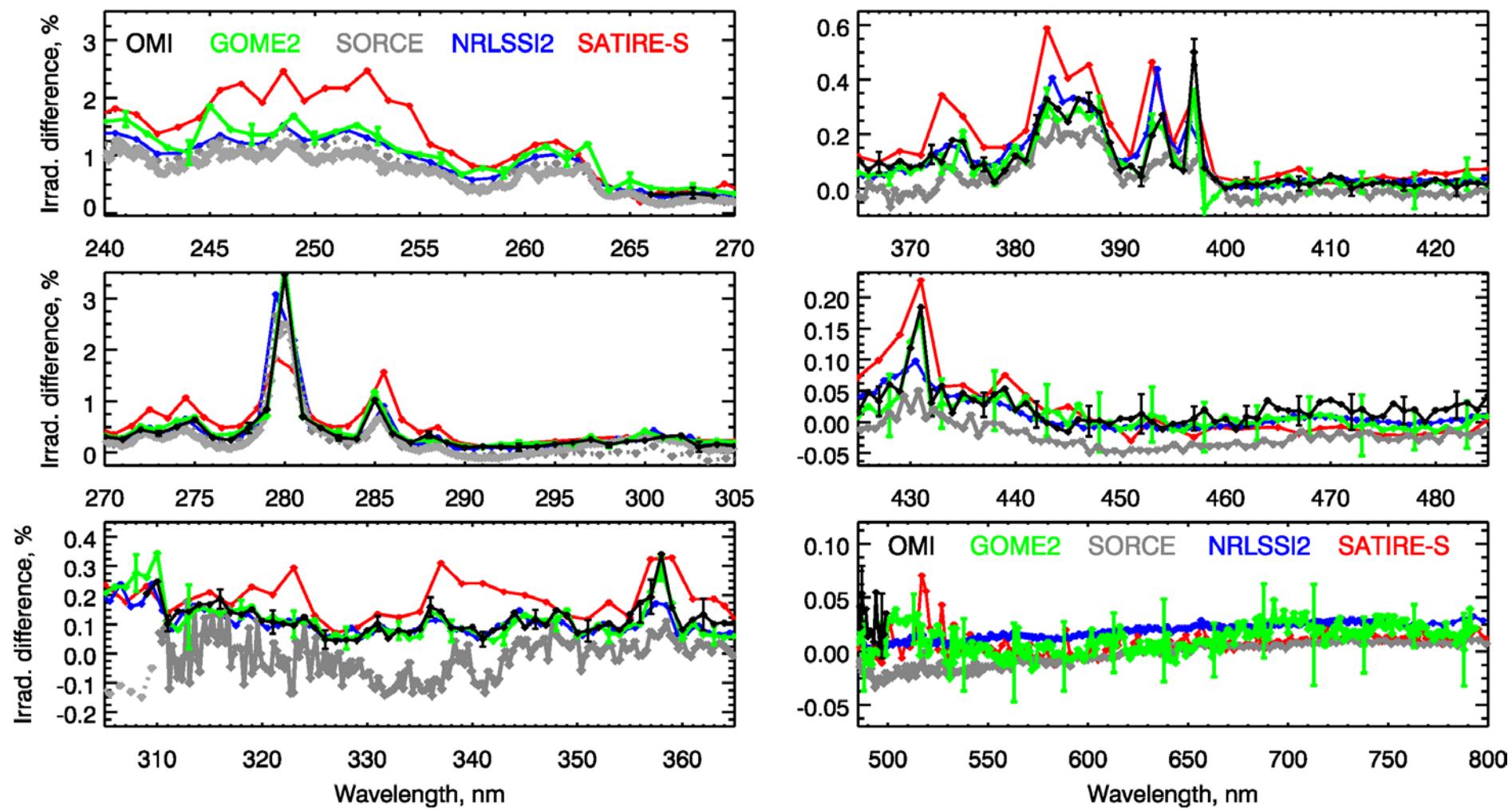
# Normalized daily SSI changes from OMI data (relative to yy2007-2009 reference)



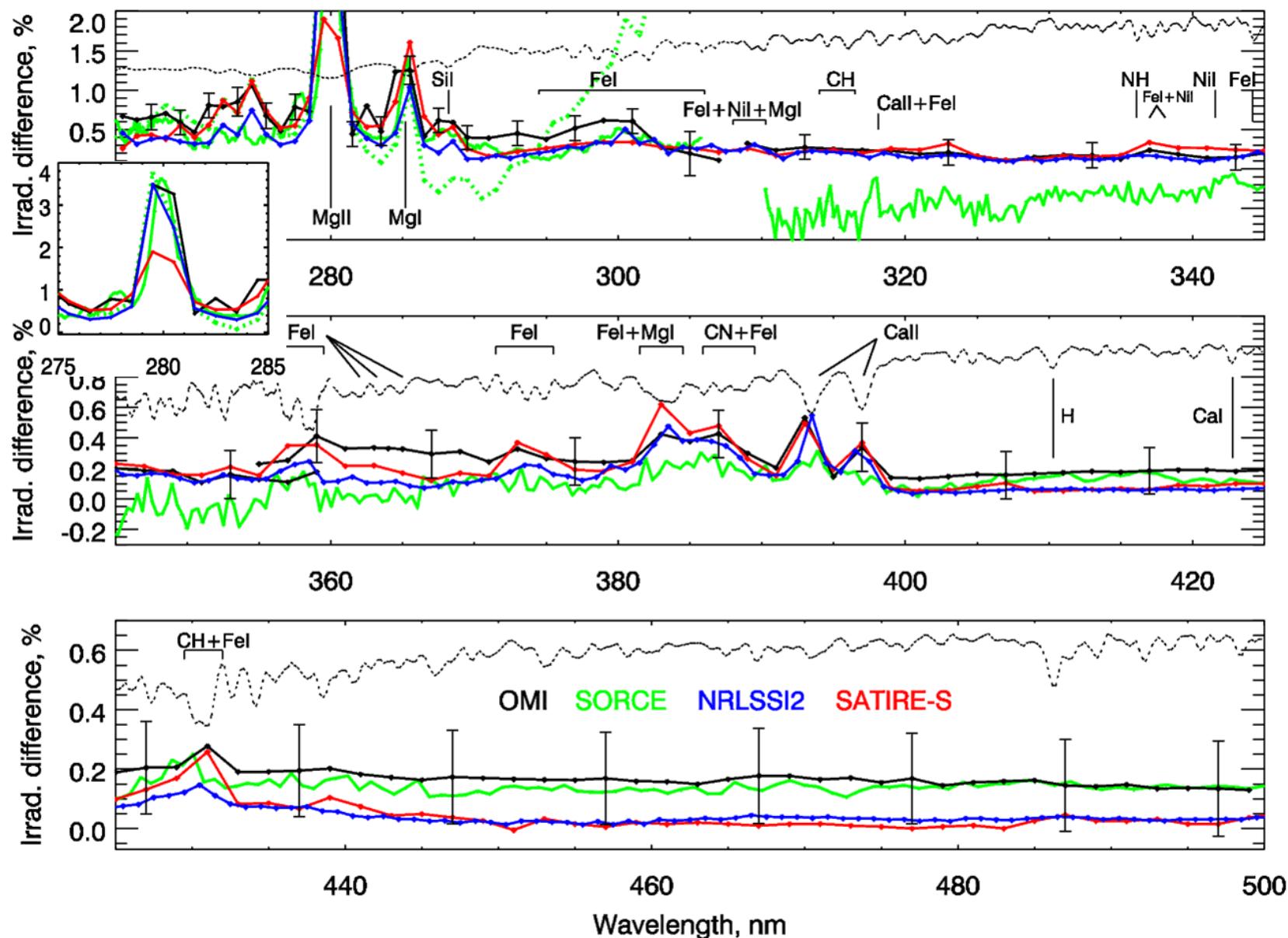
# Normalized daily SSI changes (relative to yy2007-2009 reference)



# Normalized short-term (~weekly) SSI changes from yy2012-2013

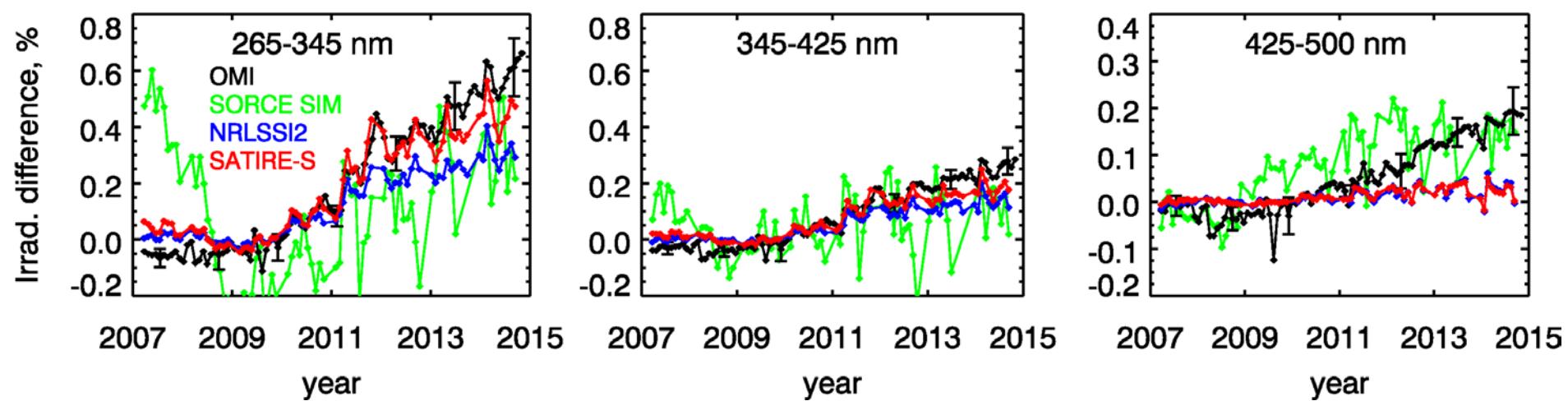


# Normalized long-term (yy2012-2014 vs. yy2007-2009) SSI changes



# The normalized and binned OMI fluxes and the models

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Short-term (~weeks) SSI variability:

OMI, SORCE, GOME-2 and NRLSSI2 [mostly] agree to  $\sim 1-2 \sigma$  ( $\sim 0.1-0.2\%$ ); problems with strong spectral lines in SATIRE-S.

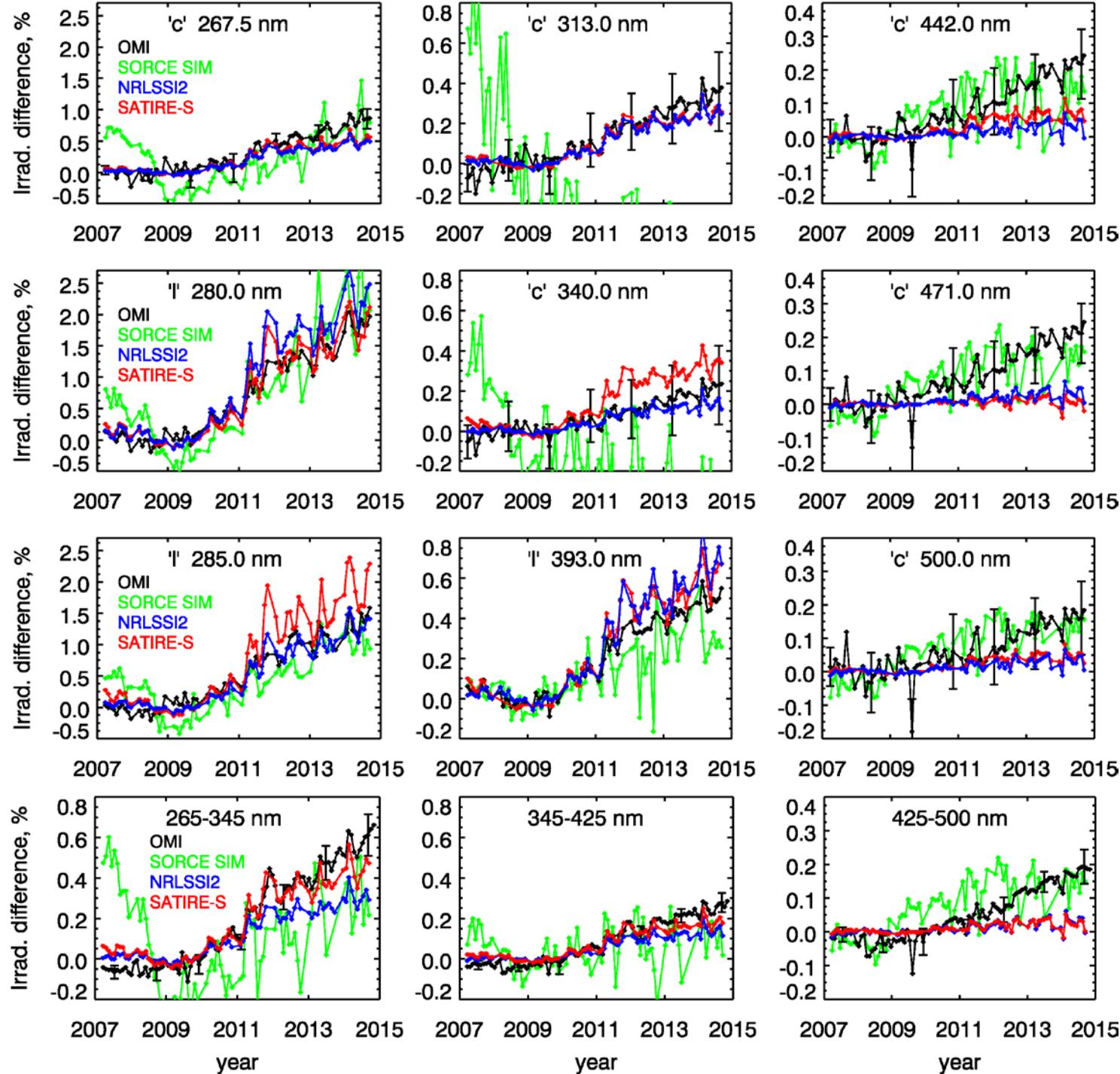
Long-term (~solar cycle) changes:

- OMI agrees with the model output at  $\sim 1-2 \sigma$  level ( $\sim 0.2-0.4\%$ );
- SORCE data cannot be reconciled with model predictions in the 290-340 nm range.

**If OMI lasts through the Cycle 24-25 minimum (at least 3 years on; ideally,  $\sim 5$  years), then we may be able to improve long-term accuracy of the SSI measurements to  $\sim 0.05\% - 0.10\%$ , thus**

- providing a unique long-term SSI record;**
- enabling further model refinements in the UV-Vis region.**

# Backup



'c' = 'continuum'  
 'l' = spectral  
 line/blend